

01-10-01

JC03 Rec'd PCT/PTO

08 JAN 2001

PCT

FORM PTO-1390  
(REV 10-2000)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371

98/07179 WO US

U.S. APPLICATION NO. (If known, see 37 CFR 1.53)

Not Yet Known

PRIORITY DATE CLAIMED  
July 8, 1998INTERNATIONAL APPLICATION NO.  
PCT/EP99/04660INTERNATIONAL FILING DATE  
July 5, 1999

TITLE OF INVENTION CHARGE CONTROL APPARATUS FOR CONTROLLING THE OPERATION OF A  
RECIPROCATING INTERNAL COMBUSTION ENGINE AND METHOD FOR  
CONTROLLING THE OPERATION OF A RECIPROCATING INTERNAL COMBUSTION ENGINE  
APPLICANT(S) FOR DO/EO/US

PAUL UITENBROEK

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☒ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 16 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.  
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☐ Other items or information:

"Express Mail" Mailing Label Number EL 707 095 599 US

Date of Deposit January 8, 2001

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Commissioner of patents and trade marks, Washington, D.C. 20231.

Evelyn L. Stump  
Evelyn L. Stump, Secretary

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)		INTERNATIONAL APPLICATION NO.		ATTORNEY'S DOCKET NUMBER	
NOT YET KNOWN <b>09/143403</b>		PCT/EP99/04660		98/07179 WO US	

17. <input checked="" type="checkbox"/> The following fees are submitted: <b>BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... <b>\$1000.00</b> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$860.00</b> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... <b>\$710.00</b> International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$690.00</b> International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$100.00</b>  <div style="text-align: right;"><b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b></div>				<b>CALCULATIONS PTO USE ONLY</b>	
				<b>\$ 860.00</b>	
Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	12 - 20 =	0	X \$18.00	\$	
Independent claims	4 - 3 =	1	X \$80.00	\$	80.00
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$270.00	\$	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				<b>\$ 940.00</b>	
<input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				<b>\$ 470.00</b>	
<b>SUBTOTAL =</b>				<b>\$ 470.00</b>	
Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
<b>TOTAL NATIONAL FEE =</b>				<b>\$ 470.00</b>	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). <b>\$40.00</b> per property				\$	
<b>TOTAL FEES ENCLOSED =</b>				<b>\$ 470.00</b>	
				Amount to be refunded:	\$
				charged:	\$

a. ☒ A check in the amount of **\$470.00** to cover the above fees is enclosed.

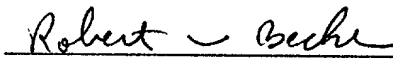
b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$\_\_\_\_\_ to cover the above fees.  
A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any  
overpayment to Deposit Account No. 02-1653. A duplicate copy of this sheet is enclosed. In the event  
there is any discrepancy in the amount sent herewith or at any time  
in the future please charge any additional fee, credit or overpayment  
to the above deposit account number.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR  
1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

**ROBERT W. BECKER & ASSOCIATES**  
 11896 N. HIGHWAY 14 SUITE B  
 TIJERAS, NEW MEXICO 87059

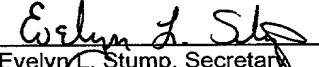
  
 SIGNATURE:  
Robert W. Becker  
 NAME  
26,255  
 REGISTRATION NUMBER

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

"Express Mail" Mailing Label Number EL 707 095 599 US

Date of Deposit January 8, 2001

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

  
Evelyn L. Stump, Secretary

In the Application of Paul Uitenbroek

Ser.No.: Not Yet Known (based on **PCT/EP99/04660** filed **July 5, 1999** and German priority document 198 30 575.3 filed July 8, 1998)

For: CHARGE CONTROL APPARATUS FOR CONTROLLING THE OPERATION OF A RECIPROCATING INTERNAL COMBUSTION ENGINE AND METHOD FOR CONTROLLING THE OPERATION OF A RECIPROCATING INTERNAL COMBUSTION ENGINE

Assistant Commissioner for Patents  
Washington, DC 20231

**PRELIMINARY AMENDMENT ACCOMPANYING ENTRY INTO NATIONAL STAGE APPLICATION**

Sir:

Prior to examination, please amend the above-identified application as follows.

**IN THE SPECIFICATION:**

On page 1, immediately after the title, please insert the following heading:

--Background of the Invention--.

On page 1, line 7, please delete ", in accordance with the introductory portion of claim 1".

On page 1, lines 9 and 10, please delete ", in accordance with the introductory portion of claim 10".

On page 2, between lines 3 and 4, please insert the following heading:

--Summary of the Invention--.

On page 2, lines 13 and 14, please delete "Those aspects of the inventive challenge relating to an apparatus are solved by the features of the main claim."

On page 3, line 1, please delete "The" and insert -- In accordance with another feature of the present invention, the" in its place.

On page 3, lines 4 and 5, please delete "Claims 3 - 6 are directed to advantageous construction details of a valve of a charge control apparatus."

On page 3, line 6, please delete "Claims 7 - 9 define a further embodiment of a valve."

On page 3, line 8, please delete "The features of claim 10 permit the invention to" and insert --In accordance with another feature of the present invention, the invention can -- in its place.

On page 3, line 9, please delete "Claim 11 defines a first solution to the challenge of providing" and insert -- In accordance with one aspect of the present invention, there is provided - in its place.

On page 3, lines 16 through 19, please delete "Claim 12 defines a second solution to the challenge of providing a method for controlling the operation of a reciprocating internal combustion engine which can be implemented as well in combination with the method recited in claim 10." and insert -- In accordance with another aspect of the present invention, there is provided a method for controlling the operation of a reciprocating internal combustion engine which can be implemented as well with the features of motors for controlling the operation of two intake valves per cylinder. -- in its place.

On page 4, lines 4 and 5, please delete "Claims 13 - 15 define a method which can be advantageously implemented in association with charging devices."

On page 4, lines 9 and 10, please delete "The invention is described in the following attached schematic drawings in an exemplary manner and with additional details."

Page 5, between lines 7 and 8, please insert the following heading:

--Brief Description of the Drawings--.

On page 25, at the bottom of the page please insert the following paragraph:

"The specification incorporates by reference the disclosure of German priority document 198 30 575.3 of July 8, 1998 and European Patent Application priority document PCT/EP99/04660 of July 5, 1999.

The present invention is, of course, in no way restricted to the specific disclosure of the specification and drawings, but also encompasses any modifications within the scope of the appended claims."

**IN THE CLAIMS:**

Please cancel claims 1 - 15, and replace them with the attached claims 16 - 27.

**IN THE DRAWINGS:**

Reference numeral 82 has been added to Figure 4 for clarification.

**REMARKS**

Claims 16 - 27 are pending in the application.

Appropriate headings have been added to the specification, a replacement abstract is attached to this preliminary amendment, and the claims from the literal translation have been replaced by claims drafted in conformity with U.S. Patent practice.

The application in its amended state is believed to be in condition for allowance. However, should the Examiner have any comments or suggestions, or wish to discuss the merits of the application, the undersigned would very much welcome a telephone call in order to expedite placement of the application into condition for allowance.

Respectfully submitted,



Robert W. Becker, Reg. No. 26,255  
for Applicant(s)

ROBERT W. BECKER & ASSOCIATES  
11896 N. Highway 14, Suite B  
Tijeras, New Mexico 87059

WHAT I CLAIM IS:

16. A charge control apparatus for a reciprocating internal combustion engine, the reciprocating internal combustion engine having at least one cylinder in which a piston is reciprocally moved by a crankshaft, the cylinder having at least one intake conduit and an intake valve which opens and closes the intake conduit as a function of the rotation of the crankshaft and having at least one outlet conduit and an outlet valve which opens and closes the outlet conduit as a function of the rotation of the crankshaft, the charge control apparatus comprising:

a rotary disc valve disposed in the intake conduit upstream of the intake valve, the rotary disc valve having a rotatable member rotably mounted in a housing and connected to an electric motor operable to move the rotatable member between a position in which the rotatable member closes the intake conduit and a position in which the rotatable member permits flow along the intake conduit to the intake valve; and

a control unit for controlling the operation of the electric motor as a function of the engine performance demand indicated by an engine performance demand element to thereby effect movement of the rotatable member of the rotary disc valve such that the closing time point of the rotary disc valve at which the rotatable member closes flow through the intake conduit is set

increasingly ahead of the closing time point of the intake valve as a function of decreasing engine performance demands.

17. A charge control device according to claim 16 and further comprising a torsion stiff and flexible connection coupling for interconnecting the rotatable member and the electric motor.
18. A charge control device according to claim 16 wherein the electric motor includes a magnetic pole rotor and the rotatable member and the electric motor are configured to operate with one another as an electro-magnetic rotational unit.
19. A charge control device according to claim 16 wherein the electric motor which includes a magnetic field winding stator, and the housing together form an electro-magnetic rotational unit.
20. A charge control apparatus for a reciprocating internal combustion engine, the reciprocating internal combustion engine having at least one cylinder in which a piston is reciprocally moved by a crankshaft, the cylinder having at least one intake conduit and an intake valve which opens and closes the intake conduit as a function of the rotation of the crankshaft and having at least one outlet conduit and an outlet valve which opens and closes the outlet conduit as a function of the rotation of the crankshaft, the charge control apparatus comprising:

a separation wall extending lengthwise within the intake conduit and having a serpentine shape and a plurality of valve

openings each extending transverse to the intake conduit length;

a shaft;

at least two closure members fixedly disposed on the shaft and each associated with a respective valve opening for opening and closing the respective valve opening in correspondence with movement of the shaft, one of the closure members being disposed on one side of the serpentine separation wall and the other closure member being disposed on the other side of the serpentine separation wall such that the pressure differential acting on the closure members in their closed positions is compensated;

a magnetic stroke actuator for moving the shaft longitudinally in one direction so as to effect closing of the valve openings in the serpentine separation wall by the respective closure members associated therewith and for moving the shaft longitudinally in an opposite direction so as to effect opening of the valve openings in the serpentine separation wall by movement of the closure members away from the valve openings; and

a control unit for controlling the operation of the magnetic stroke actuator as a function of the engine performance demand indicated by an engine performance demand element to thereby effect movement of the closure members such that the closing time point of the valve openings at which the closure members



close the valve openings is set increasingly ahead of the closing time point of the intake valve as a function of decreasing engine performance demands.

21. A charge control device according to claim 20 wherein there are four valve openings in the serpentine separation wall and four closure members each associated with a respective valve opening.
22. A charge control device according to claim 16 wherein the cylinder includes two intake conduits each having a respective intake valve associated therewith, a rotary disc valve is disposed in each intake conduit, and each rotary disc valve is connected to a separate motor for independent actuation of the rotary disc valve.
23. A method for controlling the operation of a reciprocating internal combustion engine, the reciprocating internal combustion engine having at least one cylinder in which a piston is reciprocally moved by a crankshaft, the cylinder having at least one intake conduit and an intake valve which opens and closes the intake conduit as a function of the rotation of the crankshaft and having at least one outlet conduit and an outlet valve which opens and closes the outlet conduit as a function of the rotation of the crankshaft, an engine performance demand member whose position controls the amount of fresh air charge introduced through

the intake conduit to the cylinder, and a charge control apparatus including a rotary disc valve disposed in the intake conduit upstream of the intake valve movable between a position in which the rotary disc valve closes the intake conduit and a position in which it permits flow along the intake conduit to the intake valve, the method comprising:

controlling the opening of the rotary disc valve in the intake conduit to precede the opening of the intake valve such that, when the rotary disc valve is moved into its open position in the intake conduit while the intake valve is still closed, a pressure wave produced by the vacuum existing between the rotary disc valve and the intake valve arrives, after reflection on the open end of the intake conduit, at the intake valve substantially contemporaneously with the opening of the intake valve, whereby the intake effort performed by the piston in drawing in a fresh charge into the cylinder is reduced.

24. A method for controlling the operation of a reciprocating internal combustion engine, the reciprocating internal combustion engine having at least one cylinder in which a piston is reciprocally moved by a crankshaft, the cylinder having at least one intake conduit and an intake valve which opens and closes the intake conduit as a function of the rotation of the crankshaft and having at least one outlet conduit and an outlet valve which opens and

closes the outlet conduit as a function of the rotation of the crankshaft, an engine performance demand member whose position controls the amount of fresh air charge introduced through the intake conduit to the cylinder, a separation wall extending lengthwise within the intake conduit and having a serpentine shape and a plurality of valve openings each extending transverse to the intake conduit length, a shaft, at least two closure members fixedly disposed on the shaft and each associated with a respective valve opening for opening and closing the respective valve opening in correspondence with movement of the shaft, one of the closure members being disposed on one side of the serpentine separation wall and the other closure member being disposed on the other side of the serpentine separation wall such that the pressure differential acting on the closure members in their closed positions is compensated, and a magnetic stroke actuator for moving the shaft longitudinally in one direction so as to effect closing of the valve openings in the serpentine separation wall by the respective closure members associated therewith and for moving the shaft longitudinally in an opposite direction so as to effect opening of the valve openings in the serpentine separation wall by movement of the closure members away from the valve openings, the method comprising:

controlling the movement of the closure members to effect

opening their associated valve openings in the serpentine separation wall in the intake conduit to precede the opening of the intake valve such that, when the valve openings in the serpentine separation wall in the intake conduit are open while the intake valve is still closed, a pressure wave produced by the vacuum existing between the valve openings in the serpentine separation wall in the intake conduit and the intake valve arrives, after reflection on the open end of the intake conduit, at the intake valve substantially contemporaneously with the opening of the intake valve, whereby the intake effort performed by the piston in drawing in a fresh charge into the cylinder is reduced.

25. A method according to claim 23 and further comprising controlling the movement of the closure members to open and close the valve openings in the serpentine separation wall in the intake conduit as a function of a selected one of the charging volume and the charging pressure of a charging apparatus.
26. A method according to claim 23 wherein the reciprocating internal combustion engine includes a series of exhaust gas turbochargers and an exhaust gas distribution valve is controlled to effect the immediate impact of exhaust gas on the exhaust gas turbine as a function of the control of the closure members.
27. A method according to claim 26 wherein each exhaust gas turbine includes a variable intake geometry which is controlled as a

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2
--	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	---

## Abstract Of The Disclosure

A charge control apparatus and a method for operating an reciprocating internal combustion engine are provided. The charge control apparatus includes a rotary disc valve disposed in the intake conduit upstream of the intake valve and connected to a motor and a control unit. The rotary disc valve is movable by the motor between a position in which the rotary disc valve closes the intake conduit and a position in which it permits flow along the intake conduit to the intake valve. The control unit controls the movement of the rotary disc valve into its closing position in the intake conduit such that the closing time point of the rotary disc valve is set increasingly ahead of the closing time point of the intake valve as a function of decreasing performance demands.

Charge Control Apparatus for Controlling the Operation of a  
Reciprocating Internal Combustion Engine and Method for Controlling  
the Operation of a Reciprocating Internal Combustion Engine

5           The invention relates to a charge control apparatus for controlling  
the operation of a reciprocating internal combustion engine, especially a  
gasoline engine, in accordance with the introductory portion of claim 1.  
The invention also relates to a method for controlling the operation of a  
reciprocating internal combustion engine, especially a gasoline engine,  
10 in accordance with the introductory portion of claim 10.

One of the reasons that reciprocating internal combustion engines,  
especially reciprocating internal combustion engines controlled via a  
throttle valve and operated as a four cycle engine, have an increasingly  
higher specific fuel usage in correspondence with decreasing loading -  
15 -that is, fuel usage per given work unit - is attributable to the throttle  
loss. An increasing underpressure or vacuum is formed downstream of  
the throttle valve in the volume of the suction intake between the throttle  
valve and the intake valve in correspondence with an increasingly more  
frequently closed throttle valve and this increasing vacuum reduces  
20 during the period during which the intake valve is closed. The energy  
stored in this volume which is impacted by the vacuum is consequently

lost for use otherwise as work energy. The vacuum created by the downward movement of the piston during the intake stroke causes a dissipative loading change slide in the P-V (pressure-volume) diagram.

5 The invention provides a solution to the challenge of providing a charge control apparatus for a reciprocating internal combustion engine, especially a gasoline engine, which is operable to effect an especially fuel saving operation of the reciprocating internal combustion engine. The invention further provides a solution to the challenge of providing a method for controlling the operation of a reciprocating internal combustion engine, especially a gasoline engine, such that an especially fuel saving and environmentally beneficial operation of the reciprocating internal combustion engine is possible.

10 Those aspects of the inventive challenge relating to an apparatus are solved by the features of the main claim.

15 With the help of the valve provided in accordance with the invention which is disposed in the intake channel and which is actuated by a dedicated electric motor, a charge control of an internal combustion engine in a throttle valve free manner is possible such that substantially all thermodynamically favorable charging controls can be achieved through the possible variations of the control of the rotary disc valve.

20



The efficiency of the combustion engine, particularly with respect to partial loading, is improved or, respectively, the associated fuel usage is reduced by the features of claim 2.

5 Claims 3 – 6 are directed to advantageous construction details of a valve of a charge control apparatus.

Claims 7 – 9 define a further embodiment of a valve.

The features of claim 10 permit the invention to be advantageously used for motors with two intake valves.

10 Claim 11 defines a first solution to the challenge of providing a method for controlling the operation of a reciprocating internal combustion engine. Through the special control of the rotary disc valve, it is achieved that the vacuum produced between the rotary disc valve and the intake valve in the intake channel creates a pressure wave which reduces the intake effort of the piston and thus contributes to a particularly favorable  
15 fuel economizing operation.

Claim 12 defines a second solution to the challenge of providing a method for controlling the operation of a reciprocating internal combustion engine which can be implemented as well in combination with the method recited in claim 10. With the help of the targeted modulation  
20 of the fresh air or fresh combustion gas loading which flows through the intake openings, it is possible to create, in a weak load situation, a

prescribed turbulence in the charge introduced into the cylinder or the combustion space of the type which is a prerequisite for a fuel lean and thermodynamically favorable complete combustion.

Claims 13 – 15 define a method which can be advantageously implemented in association with charging devices.

The invention is suitable for all types of valve controlled reciprocating internal combustion engines including two cycle engines, four cycle engines, Otto motors, diesel motors, and so forth.

The invention is described in the following attached schematic drawings in an exemplary manner and with additional details.

Figure 1 a conceptual view of a cylinder of a reciprocating internal combustion engine having a pre-actuated rotary disc valve,

Figure 2 a schematic view of the operation of the cylinder shown in Figure 1 during various operational phases,

Figure 3 an exploded perspective view of a rotary disc valve,

Figure 4 a side view of a rotary disc valve operable with a cylinder having two intake valves,

Figure 5 a conceptual view of a rotary disc valve for understanding a charging process,

Figure 6 a series of work diagrams of various process paths of the combustion process,

Figure 7 a side view of an embodiment of a rotary disc valve with an integrated electric motor;

5 Figure 8 a schematic view of the register charging device and

Figure 9 a sectional view of an embodiment of a rotary disc valve.

10 As seen in Figure 1, an internal combustion engine and, especially, a gasoline powered, relatively slow (low revolutions per minute) commercial vehicle engine, includes a cylinder 4 in which a piston 6 is movable, the cylinder being coupled via a piston rod 8 to a crankshaft 10 for driving rotation thereof. The designations "UT" and "OT" designate, respectively, the lowermost travel position of the piston 8 and the uppermost travel position of the piston.

15 A fresh combustion charge into the combustion space or chamber 12 of the cylinder is introduced through a suction conduit 14, whereby an intake valve 18 opens and closes the intake opening 16 at which the suction conduit 14 is communicated with the cylinder 4. An outlet valve 24 opens and closes an outlet opening 20 with respect to an outlet conduit 22 communicated therewith.

20

The ignition of the charge introduced into the combustion space 12 is effected by a spark plug 26. The intake valve 18 and the outlet valve 24 are controlled in a conventional manner by one or more camshafts, each of whose rotation is in lockstep one-to-one manner with the crankshaft 10 or rotated at a rotation other than a one-to-one rotation with the crankshaft.

A conventional device for supplying the combustion fuel (gas) to the fresh air such that a combustible fresh charge with a predetermined air to fuel mixture is available in the suction conduit 14 is not illustrated.

As is conventional, a microprocessor and an associated control unit 26 having storage capability are provided to control the operation of the internal combustion engine.

The configuration of the internal combustion engine described thus far is conventional and is not described in further detail.

A rotary disc valve 28 is disposed upstream of the intake opening 16 at the shortest possible spacing therefrom, the rotary disc valve being configured as a rotatable shaft 30 having two openings disposed oppositely one another and the rotary disc valve being operable to selectively communicate the branches of the suction conduit 14 separated from one another by the rotary disc valve or to selectively block communication between the two branches. An electric motor 32, which

can be, for example, a step motor, is controlled by the control unit 26 to drivingly rotate the rotatable shaft 30. The control unit 26 includes several input jacks comprising thereamong an input jack for connection of the control unit with a drive pedal 34. Other input jacks can be connected with a shaft rotation sensor for sensing the rate of rotation or the rotation position of the crankshaft 10, or connected with a temperature sensor, and so forth.

The internal combustion engine is preferably provided with a conventional combustion charging device such as, for example, an exhaust gas turbo charger or a mechanically driven charging device, such that a vacuum is present in the suction conduit 14 upstream of the rotary disc valve 28.

Figure 2 shows various operational phases or steps of the herein described internal combustion engine. The intake valve 18 and the outlet valve 24 are controlled such that, for example, the inlet valve opens 27.5° before OT and closes 38.5° after UT and such that the outlet valve opens 57° before UT and closes 25° after OT.

Figure 2a shows the operational condition of the intake suction during which the piston 6 has moved downwards until approximately 45° before UT while the intake valve 18 has been open and the rotary disc valve 28 has been in an open (branch communicating) disposition.

During subsequent downward movement of the piston as seen in Figure 2, the rotary disc valve 28 closes (i.e., is in a blocking disposition between the branches of the suction conduit 14), whereby a vacuum is produced in the space downstream of the rotary disc valve which reduces in a loss free manner in connection with movement of the piston beyond the lowermost dead center position until the intake valve 18 closes at 38.5° after UT.

As seen in Figure 2c, the intake valve 18 remains closed during the subsequent compression stroke of the piston, whereby Figure 2c shows the position at which the spark plug ignition occurs. During the working stroke of the piston as shown in Figure 2d, the intake valve 18 and the outlet valve 24 are in their closed dispositions and the rotary disc valve 28 can thereafter be disposed in its open disposition. Figure 2e shows the operation condition after a working stroke during which the outlet valve 24 is open for the beginning of the outlet cycle, the intake valve 18 is closed, and the rotary disc valve 28 is already in its open disposition. Once the piston has reached the position of 27.5° before OT, the intake valve 18 opens and the outlet valve 24 closes upon reaching the position 25° after OT, whereby the operational condition shown in Figure 2a is again reached shortly thereafter.

Figure 3 is a perspective view showing a parts assembly of the rotary disc valve 28 or the rotary disc valves 28 (Figure 1) couplable to a cylinder head (not illustrated), the parts assembly being shown in, respectively, assembled together condition in a) and exploded condition in b).

A housing 40 includes two connecting frames or flanges 42 and 44, one of the connecting frames being couplable to a cylinder head (not illustrated) of the internal combustion engine and the other connecting frame being couplable to the suction conduit (not illustrated). The housing 40 includes two through channels 46 and 48 configured in correspondence with connection openings formed in the cylinder head in which two suction channels independent of one another terminate, the suction channels leading to two inlet valves of a cylinder.

Throughbores 50 and 52 are located in the housing 40 oriented transversely to the through channels 46 and 48. A rotary disc valve as described hereinafter operates in each of the throughbores 50 and 52, whereby only the respective rotary disc valve in the throughbore 50 will be described.

A socket 54 compatibly configured with respect to the throughbore 50 is disposed therein and includes two openings 56 and 58 disposed opposite one another. The socket 54 is non-rotatively mounted in the

housing 40. The openings 56 and 58 are aligned with the through channels 46 and have cross sections corresponding with those of the through channels.

5 A shaft rotary disc element 60 is disposed in the socket 54 and includes a pair of openings disposed oppositely one another of which only the opening 62 is visible. The shaft rotary disc element 60 is rotatably mounted within the socket 54 and includes a rod 64 on its top closed end which is received by a connection coupling 66 that is disposed in a cover piece 68 secured by bolts to the housing 40.

10 The shaft rotary disc element is guided and mounted by means of roller bearing 70 onto guide peg 69. The guide peg 69 has the further task of conducting the mixture flow or, respectively, preventing a fluttering or flow cut off in the valve. To this end, the guide peg 69 is secured on the base plate 73 and is disposed against rotation by means of the washer 74 such that, in the disposition (by bolting) of the base plate 73  
15 on the valve housing 40, the channel throughbores 76 of the guide peg 69 are exactly aligned with the channel throughbores 46, 48 in the housing 40. The parts assembly components 71, 72 and 75 (running discs and bolts) act to position the roller bearing 70 relative to the guide  
20 peg 69. The outer diameter of the fixedly mounted guide peg 69 is only slightly relatively smaller than the inner diameter of the rotating shaft



rotary disc element 60 in order to prevent the formation of a dead space between the guide peg outer surface and the inner surface of the shaft rotary disc element 60. The free space between the two components (60 and 69) is thus selected so that an effective seal results therebetween while permitting disturbance free relative rotation therebetween.

The parts assembly components 54, 69, 60, and 62 form the rotary disc valve 28 shown in Figure 1.

As can be seen in Figure 3, the two through channels 46 and 48 can be controlled independently and separately of one another, via the rotary disc valves operating in the throughbores 50 and 52, by respective dedicated step motors, whereby, for example during reduced demand (small actuation of the drive pedal 34), an inlet channel of the cylinder remains completely closed such that the charge is delivered to the cylinder in correspondence with the configuration of the inlet channel as a swirl flow (axis of the swirl parallel to the direction of movement of the piston) or as a tumble flow (axis perpendicular to the direction of movement of the piston). As the demand increases, the two rotary disc valves are controlled such that the charges delivered through the two inlet channels are increasingly similar, whereby the swirl formation in the cylinder or the combustion space can be accommodated to that of an optimal combustion velocity/combustion operation of the motor. In this

manner, thermodynamic conditions for an effective combustion can be achieved in connection with partial charging without incurring a reduction in performance in connection with full charging of the cylinder.

Figure 4 shows a side view of the housing 40 in partial section. The housing 40, the housing cover piece 68, the rods 64 of the shaft rotary disc element 60 as well as the connection coupling 66 of the mounted step motor are clearly visible. Each connection coupling 66 includes a take along disc 80 which receives the motor shaft 82 in a non-rotating connection. The take along disc 80 is connected by a torque transmitting, flexible part 84 with another take along disc 86 which itself is connected to the rods 64 of the shaft rotary disc element 60 in a non-rotation or keyed manner. In this manner, a flexible and torsion stiff connection coupling is formed.

If the two step motors in their above-described configurations are to be differently controlled by the control unit 26 such that, for example, the shaft rotary disc element associated with the through channel 48 (Figure 3) is operated to close the through channel 48 earlier than the through channel 46 is closed, more fresh charge will flow through the through channel 46 into the cylinder, thus leading, in association with a correspondingly configured intake channel and intake valve, to the formation of turbulence in the combustion space. The differential control

of the step motors can be limited to the operational range of the motor wherein, in connection therewith, exceptional advantages can be achieved such as, for example, during weak demand. This control concept naturally comprises the possibility, in any event, to completely close an intake channel by means of the shaft rotary disc element, whereby a complete channel shut off is realized.

An extensive freedom in the selection of the opening and closing time points of the rotary disc valves relative to that of the intake valves arranged downstream of the rotary disc valves can be possible through control of the one or several rotary disc valves with the help of the electric motors 32 (Figure 1) or, respectively, the step motors 90 (Figure 4). It is possible, for example, through corresponding selection of the length of the suction conduit and the opening and closing time points of the rotary disc valve predetermined from such length selection, to use the vacuum which forms during the work phase shown in Figure 2b between the rotary disc valve 28 and intake valve 18, such that a pressure wave, which has formed during the opening of the rotary disc valve while the intake valve was still closed, reaches the intake valve at a time just as this intake valve is opening whereby the intake effort required of the piston is lessened. Moreover, the extensive freedom in the selection of the opening and closing time points of the rotary disc valves permits specific

influences to be taken into account in the selection of these opening and closing time points relative to the opening and closing time points of the intake valves downstream of the rotary disc valves, when a wave, formed by the corresponding vacuum and reflected at the open intake conduit end, arrives as a pressure wave at the end of an intake stroke at the open intake valve, whereby an after charging effect is achieved which increases the filling of the cylinder and reduces the requisite intake effort.

The above-described interrelationships are schematically shown in Figure 5. The rotary disc valve 28 divides the suction conduit 14 having an overall length  $L$  and an overall volume  $V$  into two partial regions I and II having length and volume  $L_1$ ,  $V_1$  and  $L_2$ ,  $V_2$ , respectively. The vacuum contained in the partial volume  $V_1$  occurring during the closed condition of the rotary disc valve and the intake valve produces a wave, if the rotary disc valve is opened, which is reflected on the open end of the suction conduit 100 and the wave arrives as a pressure wave at the open intake valve 18 after traversing the overall length  $L$ . Position 200 characterizes the intake valve seat so that the effective conduit length  $L$  is defined by the positions 100 and 200. This effect permits itself to be used in a wide range of motor operations as the required timing for releasing the wave formation and the reflection on the open conduit end

can be ensured through the variable opening and closing time points of the rotary disc valve 4.

It is to be understood that the variability of the opening and closing time points of the one rotary disc valve or several rotary disc valves is such that the opening time point as well as the closing time point of the total opening interval of the intake valve can be covered.

For the reason of offering freedom of control, the opening phase and, in particular, the closing phase, of the step motor controlled rotary disc valve are substantially shorter than is the case with force controlled rotary disc valves (which are driven via the camshaft having fixed force translation characteristics). In this manner, the intake cycle of the phase or, respectively, the piston stroke, is shortened while the rotary disc valve cross section limits the throttle loss.

The arrangement of the invention can be installed on motors of the type which are charged to thereby provide advantages. The advantage of the inventive arrangement for charged motors is brought out in that the function of the exhaust limit, which is normally exercised by a waste gate valve (conducting exhaust gas past a turbine wheel) is taken over by prescribed control of the one rotary disc valve or the several rotary disc valves. In this manner, in the event of reaching and/or exceeding the maximum exhaust pressure, the closing time point of the rotary disc valve

is set earlier. Thus, the cylinder charging and the amount of energy dictated thereby which is sent to the turbo charger is reduced. Through this process, the maximum achievable compression work of the compressor of the turbo charger is always ensured through the maximum release of the exhaust gas flow. No energy is lost through the waste gate valve. Through a prescribed early setting of the rotary disc valve, the desired cylinder charging amount at an optimal pressure difference between charging pressure and exhaust gas pressure of the cylinder is introduced. The above-noted optimal pressure difference causes, by the way, a positive work charging transition portion in the PV diagram. This process is known by the term Miller cycle. The inventive arrangement is an example of a specific realization of the Miller cycle.

Figure 6 shows a work diagram wherein the vertical axis indicates the logarithm of the pressure  $P$  in the work space of the cylinder and the horizontal axis indicates the volume  $V$  of the work space. OT and UT designate respectively the topmost and lowermost dead center points of the piston.

Figure 6a shows the work diagram of a throttle valve controlled four cycle motor. The individual plots indicate:

1-2: polytropic compression

2;3: isochoric heat exchange with release of the heat amount  $Q$ ,

3;4: polytropic expansion (work performance),  
4;5: isochoric heat exchange (outlet is open),  
5-6-7: isobar compression (outlet stroke),  
7;8: intake opening  
8-1: isobar intake

The striped area indicates the lost pump work; the cross hatched area indicates the work performance.

Figure 6b shows the work diagram during performance control via variable closing of the intake valve. The difference between this Figure and Figure 6a is that the exhaust stroke 5-7 and the intake stroke 7-6' occur at the same pressure level and the polytropic expansion 6'-1 and the polytropic compression 1-6' follow at the same pressure, whereby the pump loss area is zero. The point 6 or, respectively, the point 6' (closing of the intake valve) is variable.

Figure 6c shows the classic Miller cycle in which, as in Figures 6a and 6b, a heat amount Q exists at UT after the polytropic expansion from 3 to 4. The exhaust stroke 5 to 7 occurs with a relatively reduced exhaust gas counter pressure. The intake stroke from 8 to 9 occurs at a higher pressure produced by the charging system, whereby work is performed in the inclined striped area in contrast to the process shown in Figure 6a. Point 9 is the point at which the intake valve is closed.

Figure 6d shows the work diagram for a Miller cycle by which the closing of the intake valve (Point 9) is variable, whereby the total work cycle can be further optimized.

Figure 7 shows a side view of a rotary disc valve which has been changed relative to the rotary disc valve shown in Figure 3. Similarly functioning components are designated with the same reference numerals as those in Figure 3. The shaft rotary disc element 60 having its opening 62 is rotatably mounted in the housing 40 which includes the connecting flanges 42 and 44. The housing 40 is closed at both ends by coverings 102. Roller bearings 104 are disposed within the coverings 102 and are the means by which the rotor or, respectively, the shaft rotary element 60 is rotatably mounted in the housing 40.

In contrast to the embodiment shown in Figures 3 and 4, the electric motor, which is a step motor, of the embodiment shown in Figure 7 is integrated into the rotary disc valve in the form of a rotor winding 106 having alternating north and south poles rigidly connected with the rotor or, respectively, the shaft rotary disc element 60. Stator windings 108 of the electric motor are firmly connected to the housing 40 and are disposed in corresponding recesses of the housing 40.

The described arrangement forms an unusually compact rotary disc valve with an integrated step motor. The electrical connections for



controlling the stator windings 108 by means of a control unit are not illustrated.

Figure 8 shows a 6 cylinder motor provided with rotary disc valves for controlling the charging of the motor and having an additional register exhaust device.

The motor includes two cylinder banks 112 each having three cylinders which are connected via a suction conduit 114 with a mixture or air distributor 116.

In each of the suction conduits are disposed electrically actuatable rotary disc valves 118 associated with the respective two intake valves per cylinder.

The exhaust gas piping 120 of all of the cylinders are collectively communicated with a collector 122 and the exhaust gas conducted therethrough is used for the driving of the two turbochargers 124 and 126.

A conduit 130 communicates the exhaust gas collector 122 with an exhaust gas turbine 131 of the turbo charger 126 and from there, a further conduit 132 communicates with an exhaust gas turbine 133 of a turbo charger 124 from which an exhaust gas conduit 134 leads to a muffler. An electrically actuatable divider valve 140 is disposed in the conduit 130 such that a portion of the exhaust gas flow coming from the

collector 122 is branched into a branch conduit 142 which is communicated with the exhaust gas turbine of the turbo charger 124.

The charging supply of the internal combustion engine occurs such that fresh air is drawn in through an air filter 150, the fresh air is mixed in a mixing unit 152 in a prescribed relationship, which can be determined in correspondence with the operational conditions of the internal combustion engine, the charge is thereafter compressed in the charging turbine 154 of the turbo charger 124, the compressed charge is conducted via a conduit 156 through a charge air cooler 158 and thereafter to the charging turbine 160 of the exhaust gas charger 126 and from there conducted through a further charge air cooler 162 to subsequently reach the air distributor 116.

An electronic control device 164 is provided to control the rotary disc valves 118 and the distribution valves 140 as well as the turbine blade positions in the event that the inlet of the exhaust gas turbine 131 and 133 of the turbo charger 124 and 126 are outfitted with variable turbine geometry. The electronic control device 164 has inputs for receiving input from sensors which sense the operational parameters of the internal combustion engine and the position of a gas pedal 116 and has outputs connected with the denominated electrically controllable

components. The electrical connections as well as the sensors are not shown for the sake of simplicity.

The parameters for setting the rotary disc valves 118, the distribution valves 140 as well as the inlet geometries of the turbo charger 124 and 126, if present, as functions of the operational parameters of the internal combustion engine, are stored in the electronic control device 164 such that the opening and closing time points of the rotary disc valves 118 as well as those of exhaust gas volume directed to each exhaust gas turbine as well as the turbine geometries, if present, are optimally adjusted relative to one another, whereupon the required performance with the best possible efficiency of the internal combustion engine is produced.

Figure 9 shows a variation of the embodiment of the valve arranged in the suction conduit (Figure 1).

As seen in Figure 9, the suction conduit 14 has a meandering or serpentine separation wall 270 extending lengthwise of the conduit and includes four valve openings 272 each extending transverse to the suction conduit length. A valve member 274 extends transversely through the valve openings and includes a shaft 276 and a plurality of discs 278 fixedly disposed on the shaft. The arrangement is such that, in the open position of the valves shown in Figure 9, the topmost and

third topmost discs 278 are downstream of their respective associated valve openings 272 relative to the intake flow through the suction conduit and the two other discs 278 are upstream of their respective associated valve openings 272. The diameter of the discs 278 approximately corresponds to the diameter of the valve openings 272 such that the valve is closed if the shaft 276 together with the discs 278 is moved upwardly such that the discs 278 are located within the valve openings 272. The discs 278 are preferably formed in alignment with the flow.

The shaft 276 includes a cylindrical addition 280 outside of the suction conduit 14 operable to actuate the valves, the cylindrical addition 280 having a winding 282 encircled by a magnet 284 which is preferably an electromagnet and which is received in a housing 286 fixedly secured to the suction conduit 14.

The shaft 276 is longitudinally displaceably disposed within the suction conduit 14 in sockets 288. The cylindrical addition 280 is configured such that the stroke movement of the shaft 276 or, respectively, the valve member 274 is limited on the one hand by impact against the outside of the suction conduit 14 and limited on the other hand by impact against the projection of the housing 286.

A spring 290 biases the valve member 274 in its open position.

The function of the thus described valve is as follows:

The winding 282 is connected to the control unit 26 (Figure 1). The valve is normally open due to the biasing action of the spring 290. In connection with the energization of the winding 282 with corresponding electrical energy, the valve member is moved as seen in Figure 9 upwardly into a position in which the discs 278 are disposed within the valve openings 272 and a through flow of fluid through the valve openings is blocked. As can be seen, there occurs in the closed position of the valve if, for example, an overpressure exists from the left of the valve, that this overpressure acts on the topmost and third topmost discs such that the valve member is biased downwardly, whereby, in contrast, the overpressure is exerted against the bottommost and third bottommost discs to bias the valve member upwardly, whereupon the valve member in totality is in force equilibrium independent of the pressure difference.

An advantage which is realized with the depicted valve is that it can be moved in an unusually rapid manner from the closed position into the open position and vice versa, whereby a precise control is possible with the least possible loss of flow.

In a preferred configuration, the shaft 276 is connected with a position sensor 291. This position sensor 291 delivers information concerning the exact instantaneous position of the shaft 276 or, respectively, the discs 278. The control unit 26 controls the energization

through the winding 282 such that the real time position of the valve body (276, 278) corresponds at every time point of the movement sequence intervals to the prescribed positions programmed into the control unit. In this manner, it is ensured that the filling amount is the same per cylinder in multiple cylinder motors per unit control time.

It is to be understood that the electromagnetic actuation can be varied in different ways wherein, for example, the cylindrical addition 280 is configured as a magnetic anchor without its own winding. The illustrated embodiment (voice coil) has the advantage of much less magnetic attraction. The valve member can be altered together with the separation wall such that it opens or closes the valve openings by a 90° turn thereof.

The valve shown in Figure 9 can be used instead of the valve of afore-described embodiments so that the functional advantages associated with the invention can also be achieved with this configuration. The closing time point of the valve is set increasingly ahead of the closing time point of the intake valve in dependence upon decreasing performance demands. The opening time point is accommodated independently of the closing time point to the rate of rotation of the motor in order to achieve the afore-described charging effect connected with reduced intake effort.

It is advantageous if the opening time point of the valve is varied, in connection with the same maintained closing time point or, respectively, the same maintained cylinder filling amount (air effort), so as to achieve as well the charging effect to optimize the charge transition in connection with partial loading.

The depicted effect can be characterized as a partial load resonance charge for minimizing the charge transition loss.

## Patent Claims

1. A charge control apparatus for a reciprocating internal combustion engine, the reciprocating internal combustion engine having at least one cylinder (4) in which a piston (6) is reciprocally moved by a crankshaft (10), the cylinder having at least one intake opening (16) which is periodically communicated with an intake conduit (14) which terminates thereat, an intake valve (18) which opens and closes the intake opening as a function of the rotation of the crankshaft, at least one outlet opening (20), and an outlet valve (24) which opens and closes the outlet conduit as a function of the rotation of the crankshaft to thereby periodically communicate the cylinder with an outlet conduit (22) extending from the outlet opening, the charge control apparatus characterized by:

a rotary disc valve (28; 60; 62; 278; 272) disposed in the intake conduit (14) and actuated by an electric motor (28; 90; 282; 284) and

a control unit (26) for controlling the electric motor at least as a function of an engine performance demand member (34) to effect movement of the rotary disc valve such that the closing time point of the rotary disc valve is set increasingly ahead of the



closing time point of the intake valve as a function of decreasing performance demands.

2. A charge control device according to claim 1 characterized in that the opening time point of the rotary disc valve is varied in connection with the same maintained closing time point of the intake valve or, respectively, the same maintained cylinder filling amount (air effort) as a function of the rate of rotation of the reciprocating internal combustion engine so as to optimize the charging transition in connection with partial loading.
3. A charge control device according to claim 1 or 2 characterized in that the rotary disc valve (28; 60, 62) includes a rotatable shaft (30; 60) rotatably mounted in a housing (40) which is directly driven by the motor (32; 90) which is an electric step motor.
4. A charge control device according to claim 4 and characterized in that a torsion stiff and flexible connection coupling (66) is arranged between the rotatable shaft (60) and the electric motor (90).
5. A charge control device according to claim 3 or 4 characterized in that the electric motor includes a magnetic pole rotor and the rotatable shaft (60) and the electric motor are configured to operate with one another as an electro-magnetic rotational unit.
6. A charge control device according to one of claims 3 - 5

characterized in that the housing (40) includes a magnetic field winding stator.

- 5
7. A charge control device according to claim 1 or 2 characterized in that the valve member (274) includes a shaft (276) actuated by the electric motor (282, 284), a separation wall (270) in the intake conduit, and valve openings (272) formed in the separation wall (270), and at least two closure members (278) fixedly disposed on the shaft and each associated with a respective valve opening for opening and closing the respective valve opening in correspondence with movement of the shaft such that the pressure differential acting on the closure members in their closed positions is compensated.
- 10
8. A charge control device according to claim 7 and characterized in that the shaft (276) extends transversely through the intake conduit (14) and is longitudinally movable by a magnetic stroke actuator (282, 284) and the closure members (278) are discs which encircle the shaft and which are provided along the serpentine separation wall (270) extending longitudinally in the intake conduit, whereby, with respect to the direction of flow
- 15
- 20
- through the intake conduit, the closure members are arranged in the open disposition of the valve on differing sides of the valve

openings.

9. A charge control device according to claim 8 characterized in that four valve openings (272) are provided with associated closure members (278).

- 5 10. A charge control device according to one of claims 1 - 9 characterized in that the cylinder includes two intake conduits (46, 48) with associated intake valves, a rotary disc valve (54, 60) is disposed in each intake conduit, and each rotary disc valve is connected to a separate electric motor (90) for independent  
10 actuation of the rotary disc valve.

11. A method for controlling the operation of a reciprocating internal combustion engine, the reciprocating internal combustion engine having at least one cylinder (4)) in which a piston (6) is reciprocably moved by a crankshaft (10), the cylinder having at  
15 least one intake opening (16) which is periodically communicated with an intake conduit (14) which terminates thereat and an intake valve (18) which opens and closes the intake opening as a function of the rotation of the crankshaft and having at least one outlet opening (20) and an outlet valve (24) which opens and  
20 closes the outlet conduit as a function of the rotation of the crankshaft to thereby periodically communicate the cylinder with

an outlet conduit (22) extending from the outlet opening, whereby an engine performance demand member (34) is provided whose position dictates the amount of fresh air charge introduced through the intake opening, the method characterized by:

5                   controlling the movement of a rotary disc valve (28; 60; 62; 278; 272) disposed in the intake conduit (14) at least as a function of the engine performance demand member (34) to effect movement of the rotary disc valve such that the closing time point of the rotary disc valve is set increasingly ahead of the closing time point of the intake valve (18) as a function of decreasing performance demands and

                  controlling the movement of the rotary disc valve into its opening position so as to create a pressure wave which moves through the open intake valve into the cylinder.

- 15           12.   A method for controlling the operation of a reciprocating internal combustion engine, the reciprocating internal combustion engine having at least one cylinder (4) in which a piston (6) is reciprocally moved by a crankshaft (10), the cylinder having at least one intake opening (16) which is periodically communicated with an intake conduit (14) which terminates thereat and an intake valve (18) which opens and closes the intake opening as a function of the

rotation of the crankshaft and having at least one outlet opening (20) and an outlet valve (24) which opens and closes the outlet conduit as a function of the rotation of the crankshaft to thereby periodically communicate the cylinder with an outlet conduit (22) extending from the outlet opening, whereby an engine performance demand member (34) is provided whose position dictates the amount of fresh air charge introduced through the intake opening,

the method characterized by:

controlling the movement of a rotary disc valve (60, 62) associated with a respective intake conduit (46, 48) independent of the movement of another rotary disc valve associated with another intake conduit as a function of the position of the engine performance demand member (34) such that, in connection with decreasing performance demands, the charging amount introduced through the two intake conduits is different.

13. A method according to claim 11 or 12 characterized in that the charging volume or, respectively, the charging pressure of a charging apparatus are controlled as a function of the movement of the rotary disc valve or the rotary valves (60, 62).

14. A method according to claim 11 or 12 characterized in that the

reciprocating internal combustion engine includes a series of exhaust gas turbo chargers and an exhaust gas distribution valve is controlled to effect the immediate impact of exhaust gas on the exhaust gas turbine as a function of the control of a rotary disc valve.

5

15. A method according to claim 14 characterized in that each exhaust gas turbine includes a variable intake geometry which is controlled as a function of the control of the rotary disc valve or the rotary disc valves.

10

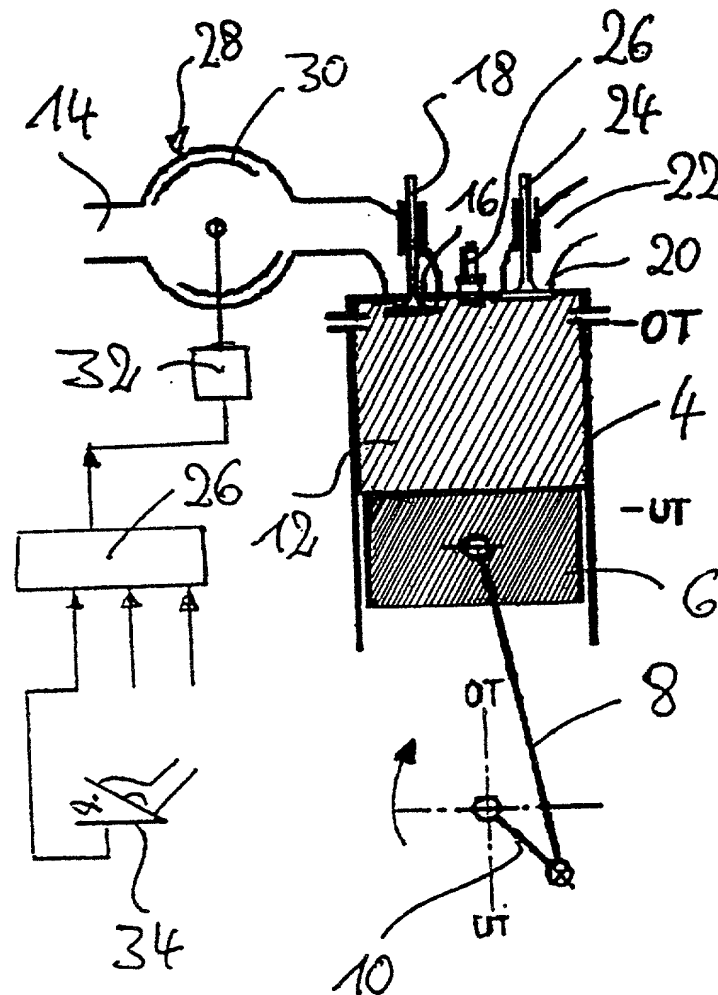
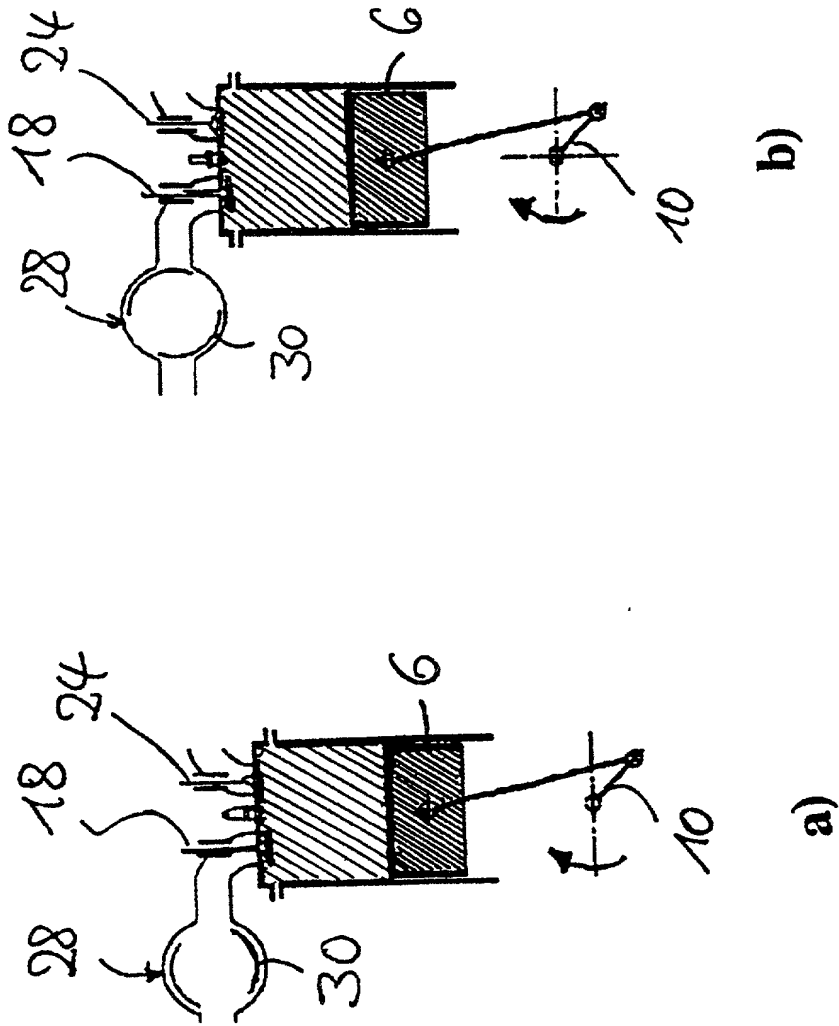
**Fig. 1**

Fig. 2





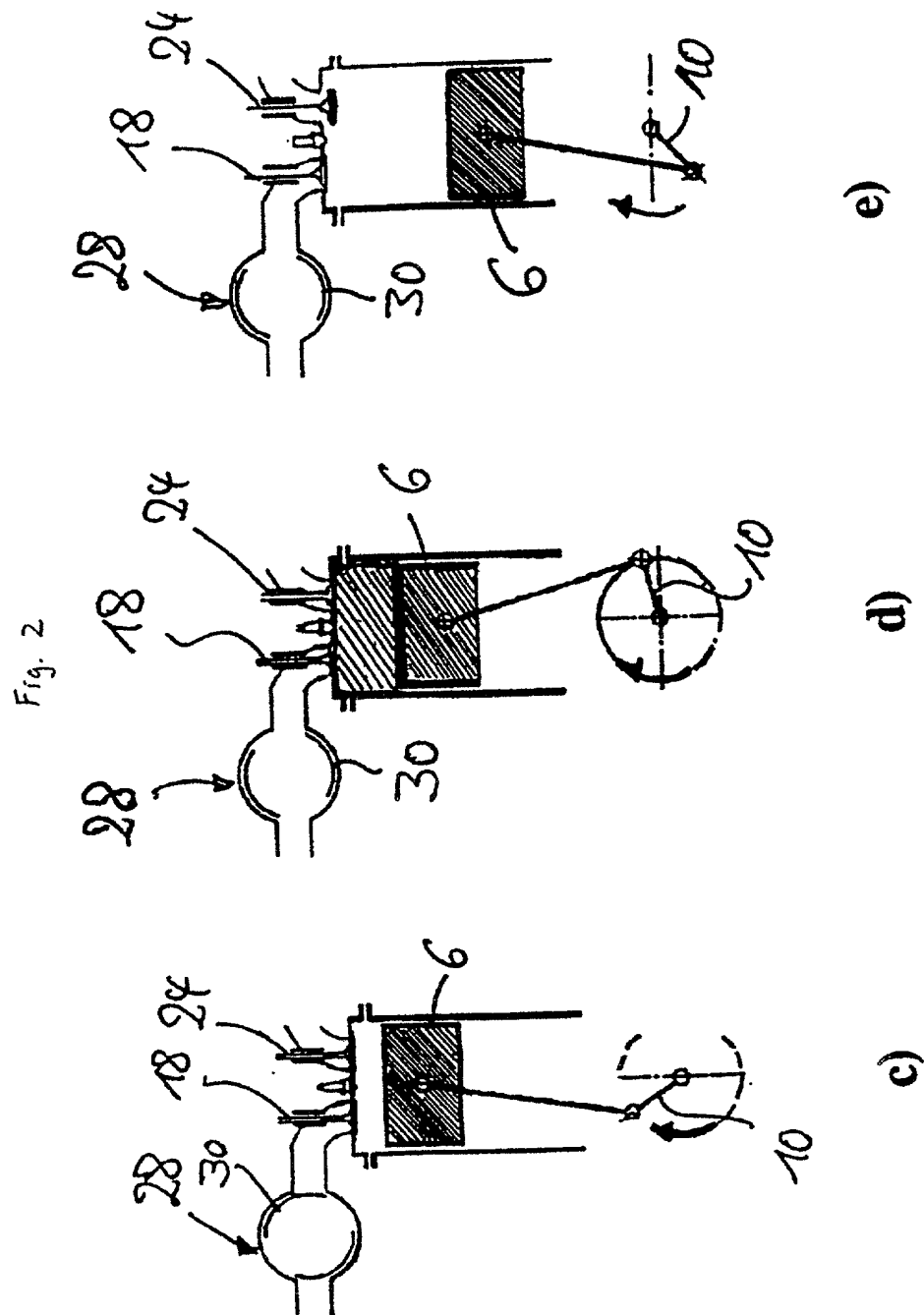


Fig. 3

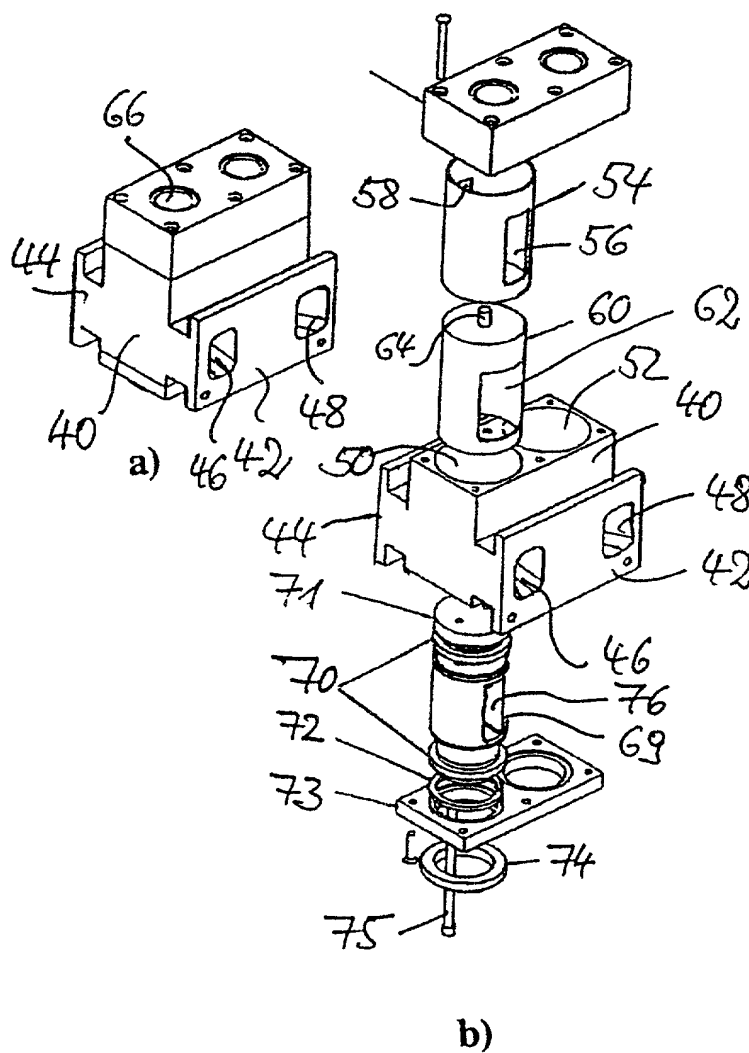


Fig. 4

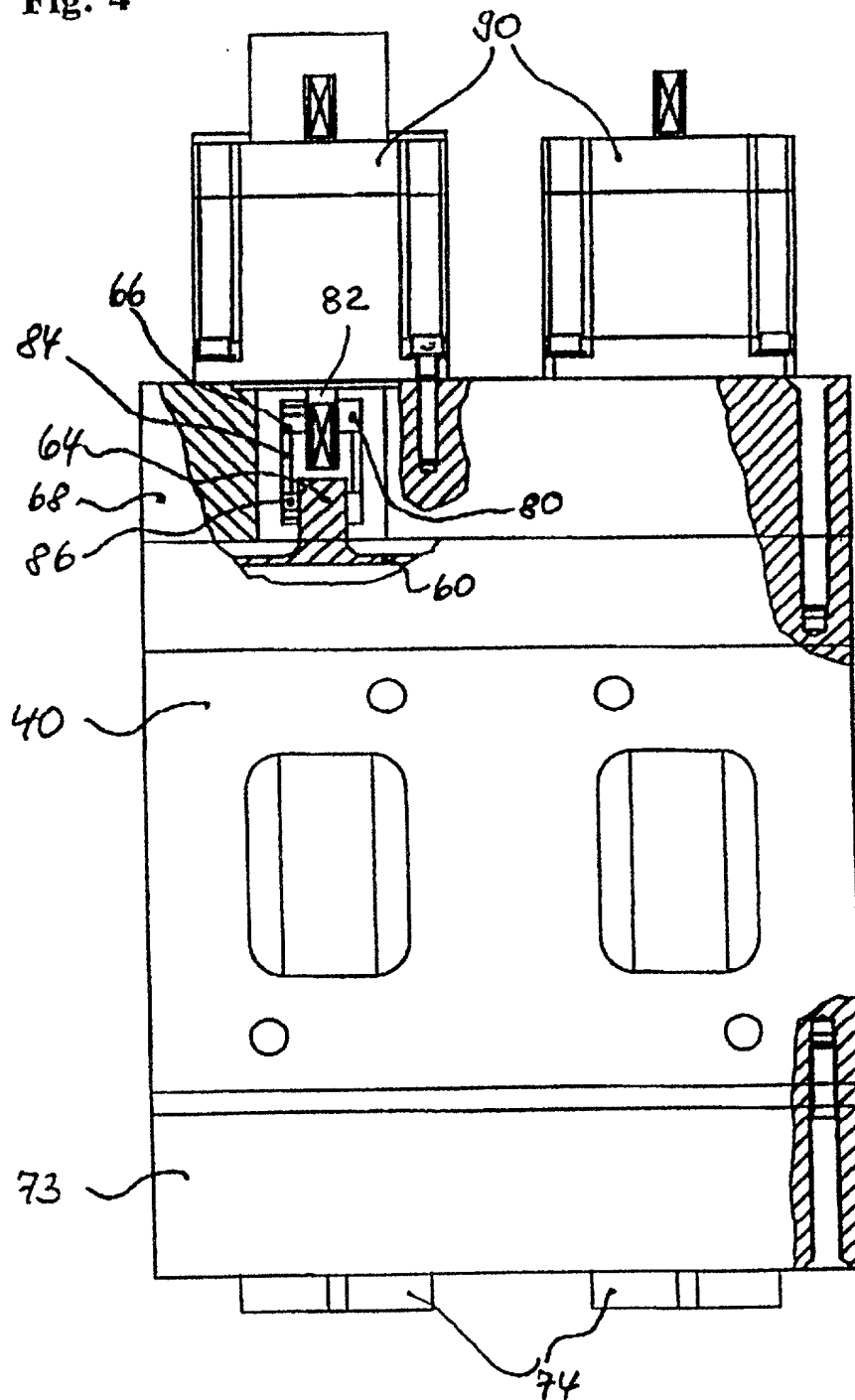


Fig. 5

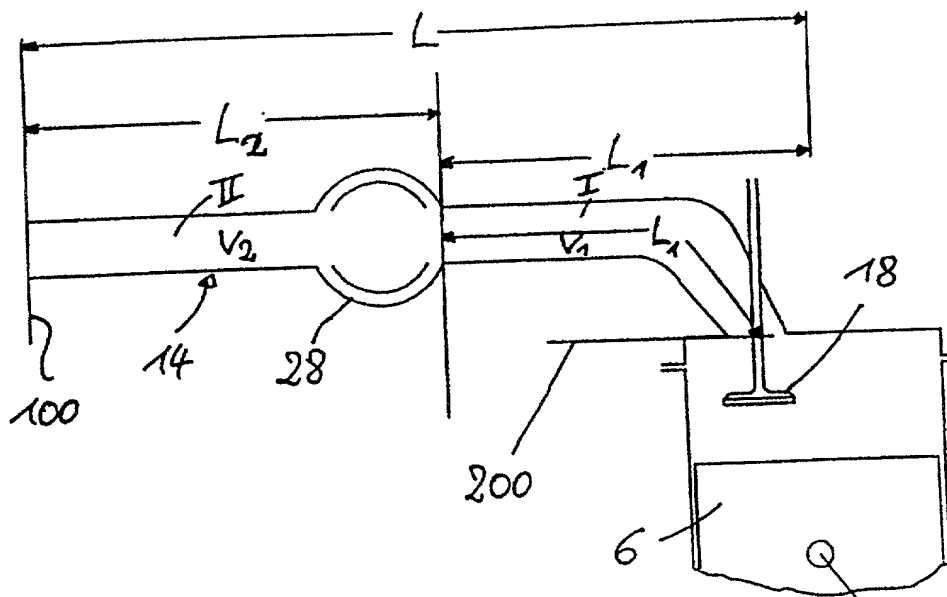
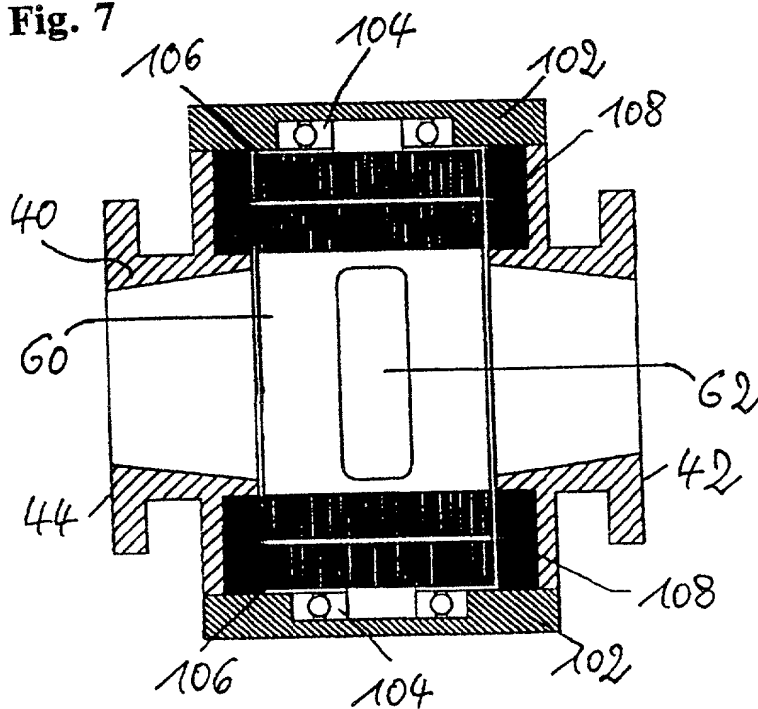


Fig. 7



**Fig. 6**

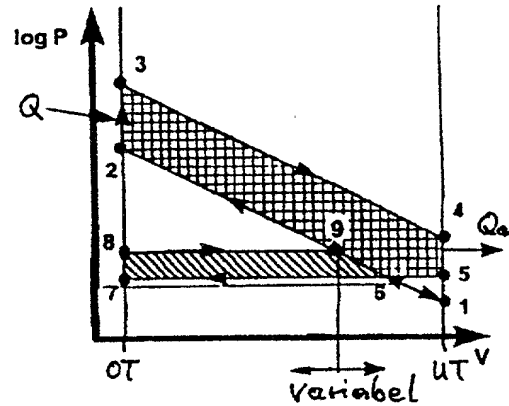
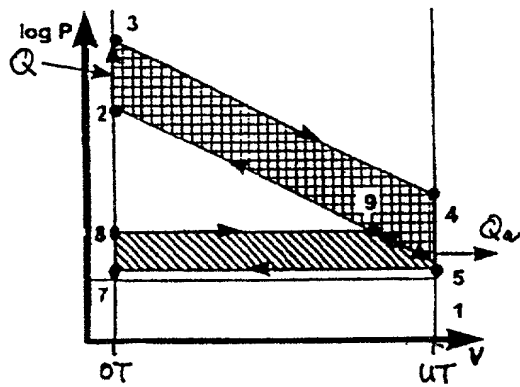
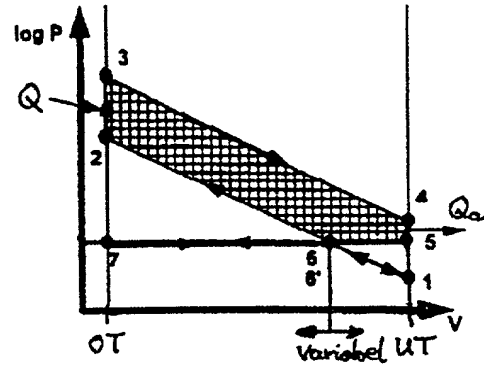
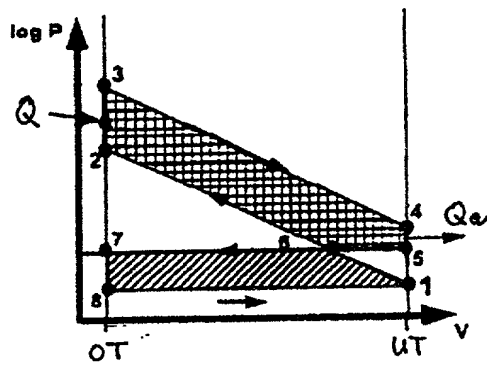
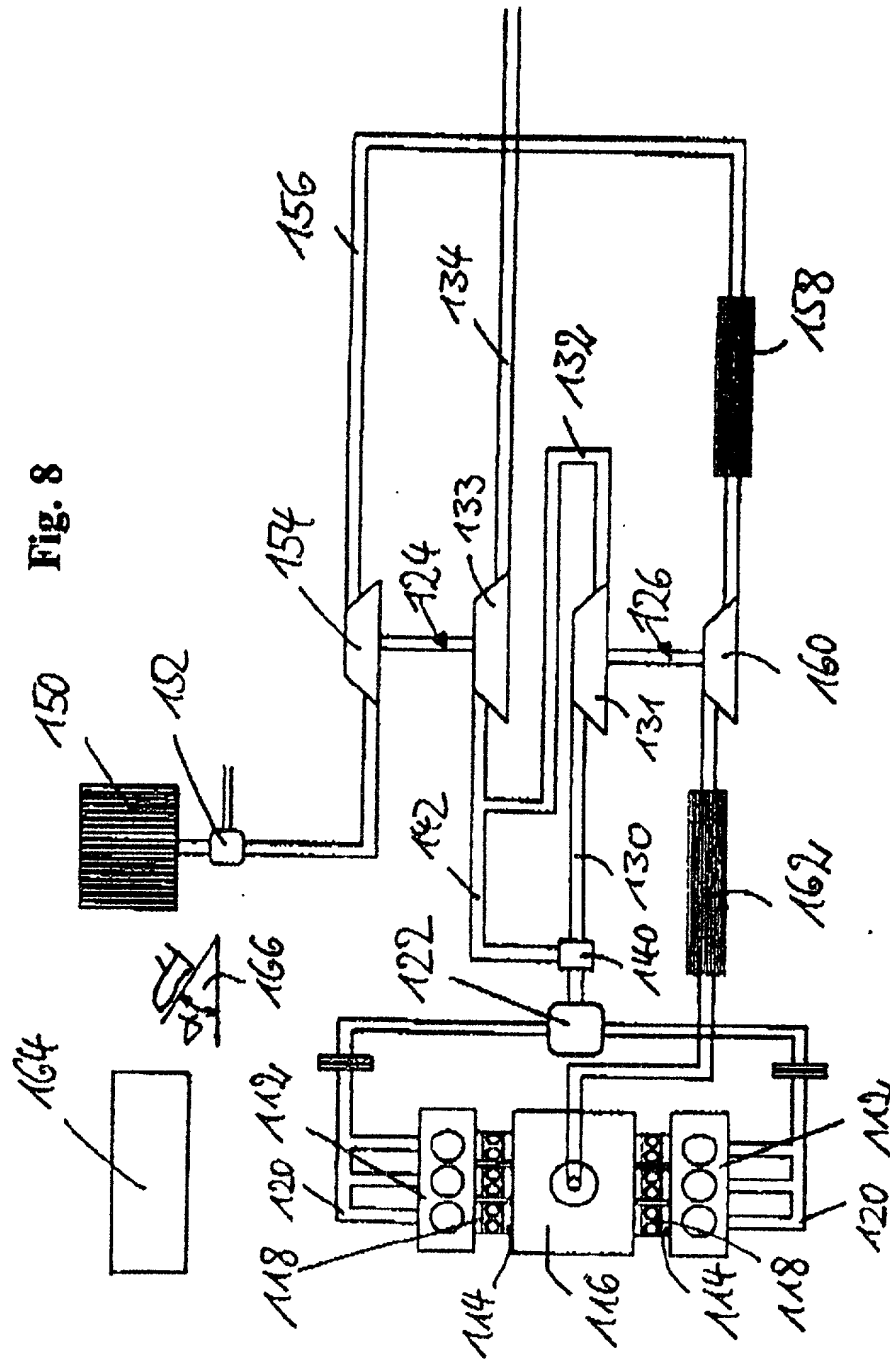


Fig. 8



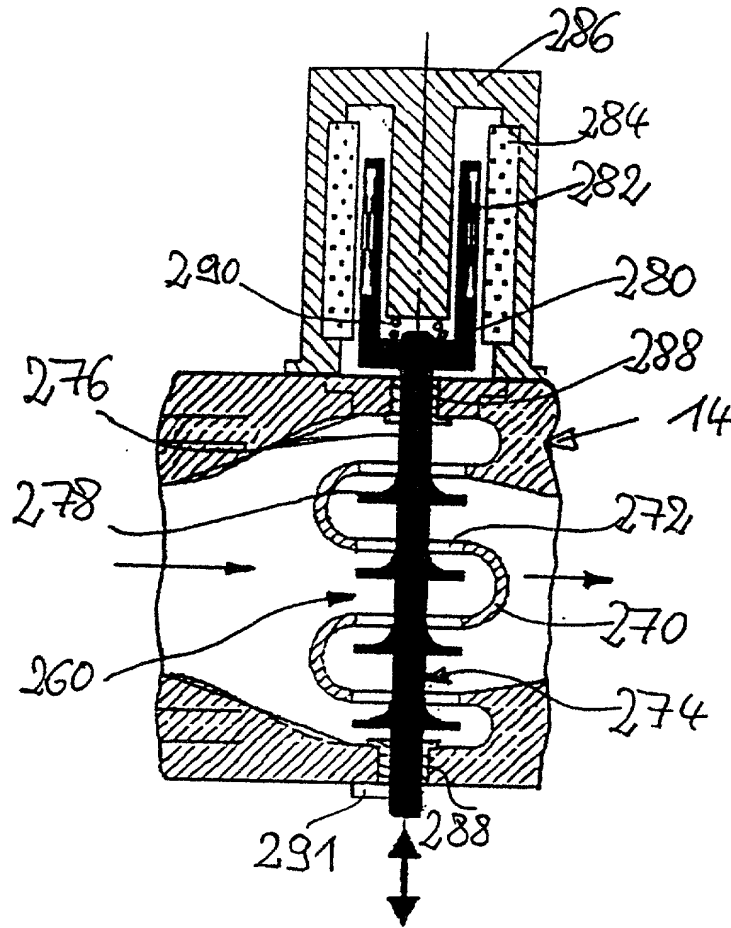


FIG 9



FEB 08 2001

PATENT &amp; TRADEMARK OFFICE

FEB 2001

Attorney Docket No.

98/07179 WO US

## COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought of the invention entitled: Charge Control Apparatus for Controlling the Operation of a Reciprocating Internal Combustion Engine and Method for Controlling the Operation of a Reciprocating Internal Combustion Engine

is attached hereto;

XX was filed on July 5, 1999 as International Application Ser.No. PCT/EP99/04660 and was amended on January 8, 2001, on which date U.S. application S.N.09/743,403 was filed.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information known by me to be material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):

Priority  
Claimed

<u>198 30 575.3</u> (Number)	<u>Germany</u> (Country)	<u>08/07/1998</u> (Day/Month/Year Filed)	<u>X</u> Yes No
---------------------------------	-----------------------------	---	--------------------

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below:

(Application Number)

(Filing Date)

I hereby appoint attorney Robert W. Becker, Reg. No. 26,255, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith. Address all telephone calls to (505) 286-3511. Address all correspondence to ROBERT W. BECKER & ASSOCIATES, 11896 N. Highway 14, Suite B, Tijeras, New Mexico 87059.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor: Paul Uitenbroek

Inventor's signature P. Uitenbroek

Date: 11<sup>th</sup> January 2001

Residence: Südstrasse 43, D-52314 Kohlscheid, Germany

Citizenship: Netherland

Post Office Address: Same as above